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DISCREPANCIES IN THE OBSERVED "PLASMA-TROUGH" DENSITY

E. J. R. MAIER
G. P. SERBU

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GSFC

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

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by

E.J.R. Maier and G.P. Serbu
Laboratory for Planetary Atmospheres
Goddard Space Flight Center
Greenbelt, Maryland

ABSTRACT

Observations of the plasmapause have now been achieved by a variety of techniques - ground based reception of Whistlers, and in-situ observations by mass spectrometers, retarding analyzers, and VLF receivers. Comparisons of some of these observations are made and it is concluded that the details of the plasmasphere boundary and the thermal plasma density beyond the plasmasphere are more variable than the idealized plasmasphere model would suggest.

Carpenter, in a classic paper published in 1966, described the plasma surrounding the earth as contained in a "plasmasphere" having a sharply defined outer boundary, beyond which the plasma density was of the order of $1/cm^3$. His results were derived from Whistler dispersion observations which are somewhat dependent on the model plasma distribution assumed within the plasmasphere and which tend to emphasize the plasma distribution near the magnetic equatorial plane. In addition, the acquisition of Whistler data from a specific region in space is dependent upon the probability of propagation of Whistler through the particular region.

Recently a number of spacecraft carrying retarding analyzers, mass spectrometers, and VLF receivers have traversed the plasmasphere/plasma trough region obtaining data along specified

trajectory paths. In this note we compare results obtained by various experimenters which demonstrate that the plasma density in the trough region may not always be the 1 ion/cm^3 stated in the idealized model.

In a recent paper Harris, Sharp and Chappell [1970] have criticized the IMP II electron results [Serbu and Maier, 1966a] for ... "not [having] always clearly shown the presence of the plasmapause". Their criticism is along the same general lines expressed by Gringauz [1969]..."In the interpretation of the data from this experiment (IMP II electron measurement) the authors (op. cit.) did not detect the knee in the distribution of charged particle density". These criticisms are based in part on our statement ... "as can be seen, neither of the density profiles of Figure 4 and 5 indicate a knee-type of fall-off in the region from 3 to 5 R_E; in fact, our density of 5 R_E is just about a factor of 10 above that reported by Angerami and Carpenter [1966]".

Experimental evidence obtained first with the Pioneer I Quadrispherical Plasma Probe by Wolfe et al. [1967] and later with the Explorer 35 Retarding Potential Analyzer by Serbu [1969] indicates that as a consequence of solar particle and ultraviolet radiation a secondary electron sheath may envelop a sunlit spacecraft. The density of the photoelectrons can exceed the density of the ambient electrons and as a consequence, a valid measurement is not easily made in regions of very low electron density. Whipple and Parker [1969a] have developed

the theoretical response function for a Retarding Potential Analyzer experiment operating in a tenuous plasma in sunlight. They show that the response characteristic for the electron current-voltage (I-V) curve contains a primary, or ambient, component and a secondary emission component. Using experimental data from the OGO-I spacecraft, in the solar wind region, they also show that some of the secondary electrons are in ballistic trajectories escaping from and returning to the spacecraft, and moving with thermal energies in the range from 1 to 5 eV. Correcting our IMP-II [op. cit.] electron density values for the secondary component will not significantly change the shape of the electron density profiles within the plasmasphere; however, it will result in density values lower than originally reported for the region beyond the plasmapause. Structure in the density at the plasmapause is evident in data published by us [Serbu and Maier, 1966a], but due to the editorial requirement for brevity these profiles were omitted from the Journal of Geophysical Research publication. Note that Carpenter's [1966] original definition for the "knee" was a variation in the plasma density of 100 to 1 over a radial distance increment of 0.1 R_E. We used this definition in noting the absence of a "knee" in our Figure 4 and 5 [op. cit.] data.

There is a large body of published data which we cite in support of our claim [Serbu and Maier, 1970] that the plasma density on the far side of the plasmapause exceeds the value

of 1 electron/cm^3 given by Carpenter [op. cit.], see Figure 1. Chappell et al. [1970] claim to establish as a final value a density of <10 cm^{-3} for the plasma trough region. In Figure 2 we present their spectrometer data from OGO-5 which clearly shows a density of 100 ions/cm^3 at L = 9.

Carpenter et al. [1969] presented the data of Figure 3 which shows the simultaneous V.L.F. and ion mass spectrometer data used to detect the plasmapause on July 5, 1966. They have identified the plasmapause at 4.6 R_E, where the observed ion density drop-off is a factor of 8 over a radial distance of 0.5 R_E. The plasma trough density measured on July 5, 1966 was in the range from 100 to 20 ions/cm^3, which is also at variance with the criteria set up by Chappell et al. [op. cit.] for the plasma trough value of <10 ions/cm^3. In Figure 4 we present the density data of Bezrukikh [1968] obtained from Electron 4. In the author's own words ... "The distribution of n_i, presented in Figure 6, gives grounds to believe that at the geomagnetic latitudes $\varphi > 45^o$ the actual distribution of charged particle density in some cases may considerably differ from the idealized model, suggested by Carpenter [1966]".

In Figure 5 we present data of Vasyliunas [1968] which we offer in heuristic support to our contention for the intermittent existence of higher densities in the trough region. The mean electron energy versus density data of OGO-I and Vela [Bame et al. 1967] indicate that within the region of the plasma trough the density at 10 eV should be in the range 15 to 100 cm^{-3}. We see

no reason for assuming that the generalized Maxwellian distribution function derived by Vasyliunas to adequately describe the energy density relationship as measured from 10,000 eV to 30 eV should require an abrupt modification at 10 eV.

Thus, we conclude there is evidence to indicate that the morphology of the plasma trough is both time and space dependent. In addition the plasma trough position and the character of the boundary may be dependent upon the energy interval used in the observation. At equatorial latitudes thermal particles, viz. the plasma component observable through Whistlers, have a temporal and spatial structure which at times agrees with and at other times is markedly different from that observed at higher energies [Schield and Frank, 1969] or at greater latitudes, Bezrukikh op. cit. For particles of energies less than 10 eV, there may exist external mechanisms such as photoemissions, secondary emission and spacecraft potential changes which can bring about a shift in the energy interval of the observation. Whipple and Parker [1970] calculate that for experiments which sample the ambient plasma more than one order of magnitude effects can be caused by small changes in the spacecraft potential. Results from long term observations, Serbu and Maier op. cit. and Taylor [1970] indicate that a high degree of variability exists in the plasma trough structure, that is, in the density, density gradients and location of the drop-off.

LIST OF FIGURES

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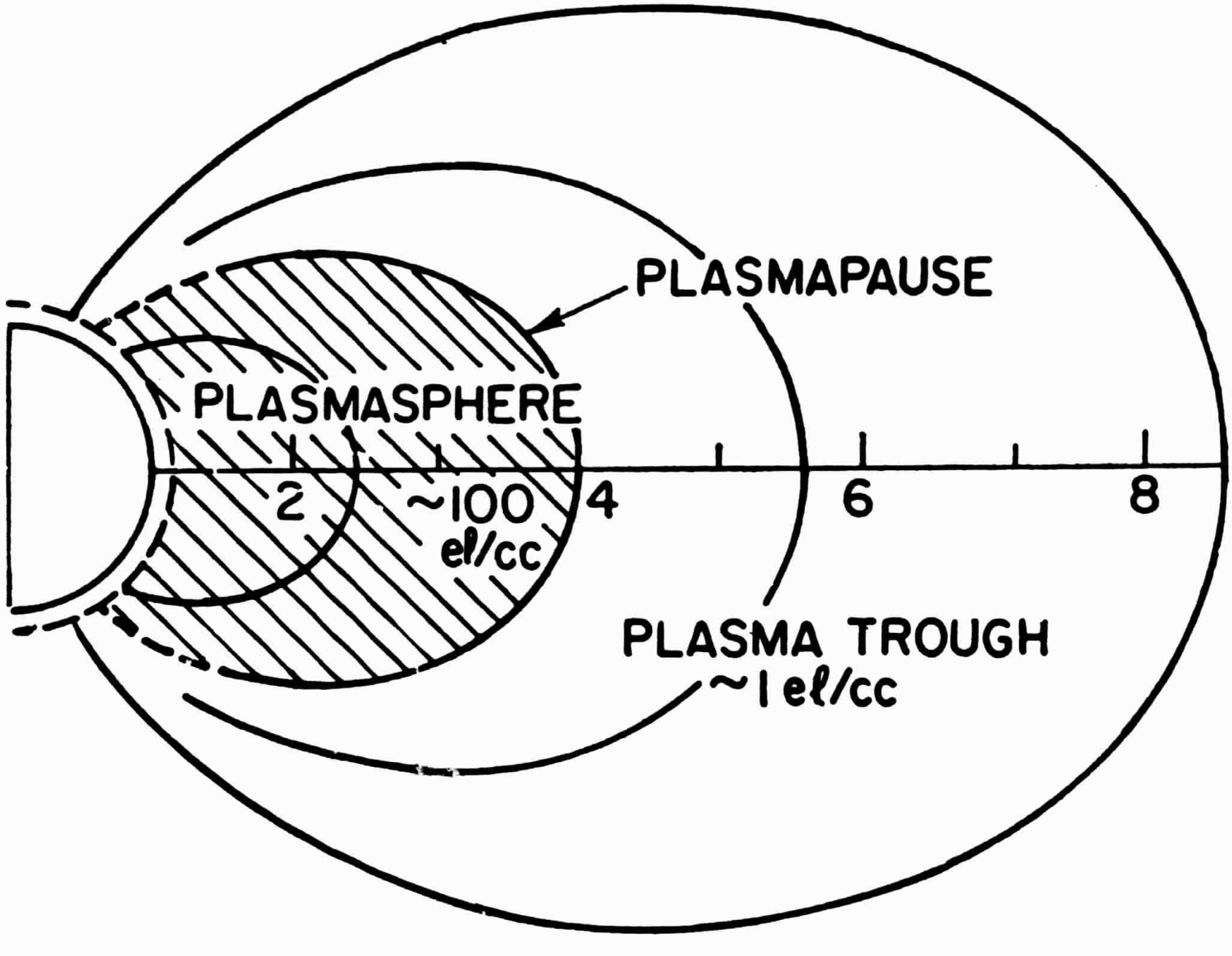
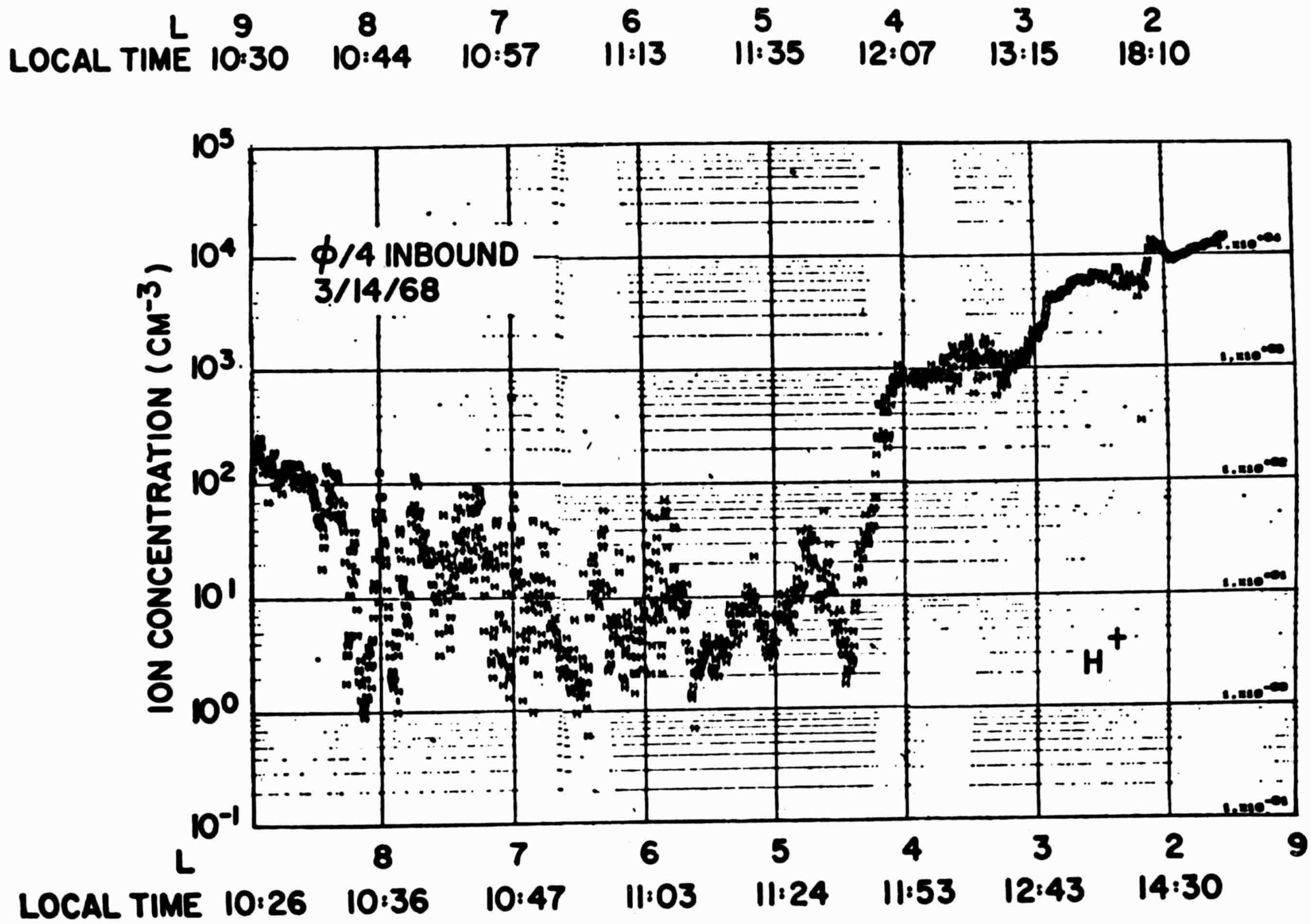
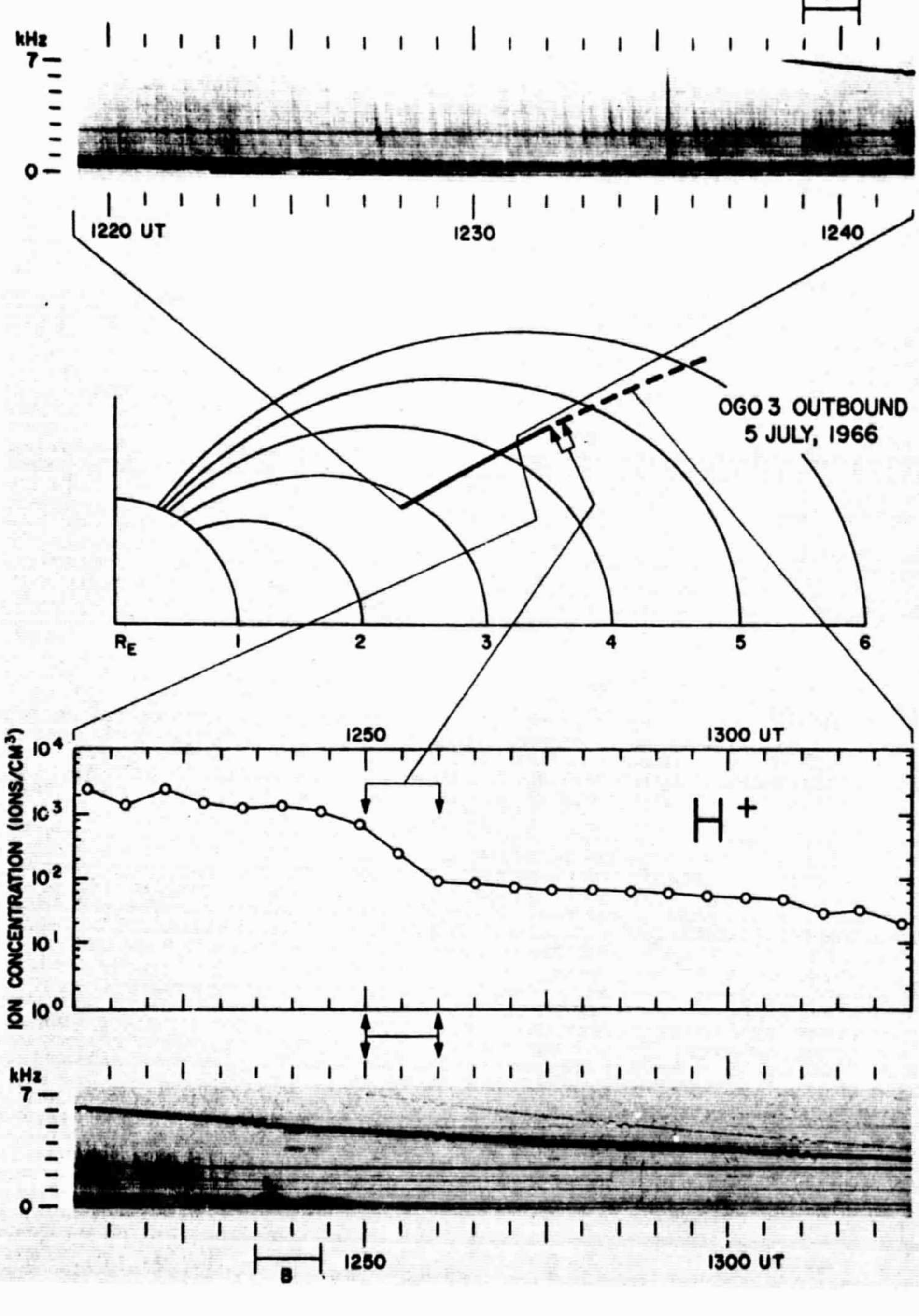

PLASMAPAUSE
PLASMASPHERE
2
~100
el/cc
4
6
8
PLASMA TROUGH
~1 el/cc

Figure 1



L 9 8 7 6 5 4 3 2
LOCAL TIME 10:30 10:44 10:57 11:13 11:35 12:07 13:15 18:10
ION CONCENTRATION (CM⁻³)
10⁵
10⁴
10³
10²
10¹
10⁰
10⁻¹
φ/4 INBOUND
3/14/68
H+
L 8 7 6 5 4 3 2 9
LOCAL TIME 10:26 10:36 10:47 11:03 11:24 11:53 12:43 14:30

Figure 2



A
kHz
7
0
1220 UT
1230
1240
OGO 3 OUTBOUND
5 JULY, 1966
R_E
1
2
3
4
5
6
1250
1300 UT
10^4
10^3
10^2
10^1
10^0
ION CONCENTRATION (IONS/CM³)
H+
kHz
7
0
B
1250
1300 UT

Figure 3

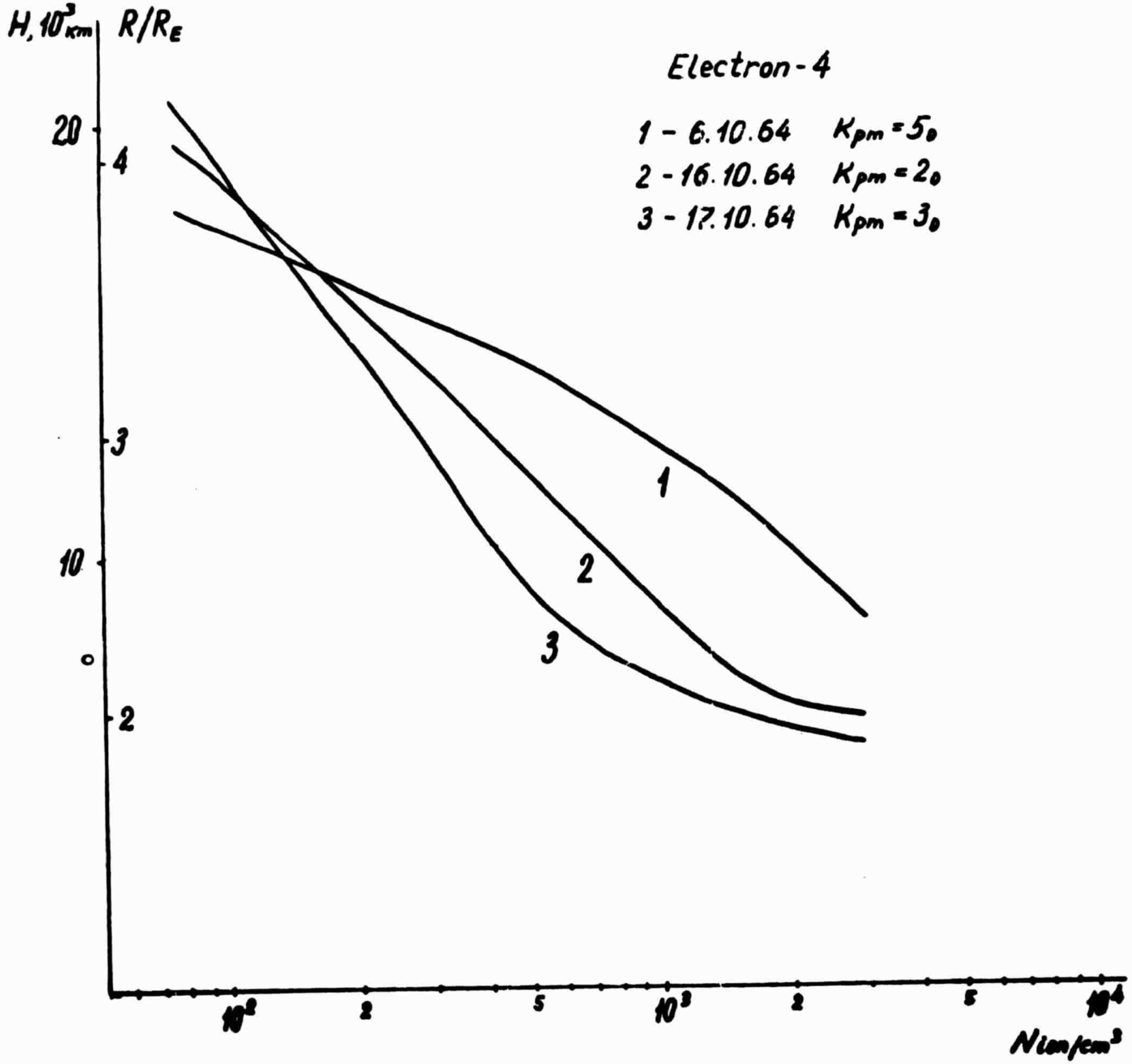

H, 10³ km
R/R_E
Electron-4
1 - 6.10.64 Kpm = 5₀
2 - 16.10.64 Kpm = 2₀
3 - 17.10.64 Kpm = 3₀
20
10
4
3
2
1
2
3
10²
2
5
10³
2
5
10⁴
N ion/cm³

Figure 4

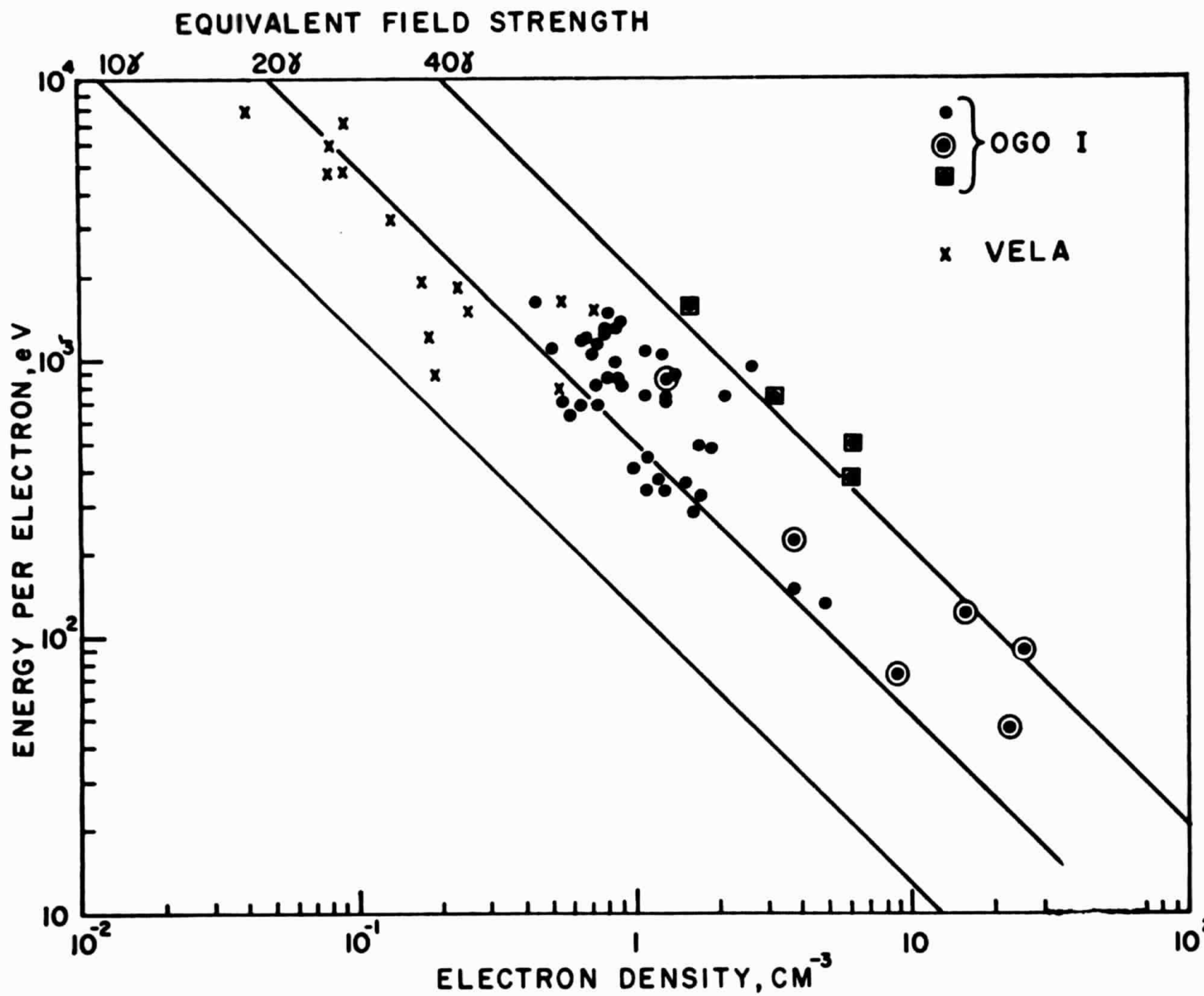

EQUIVALENT FIELD STRENGTH
10γ
20γ
40γ
OGO I
VELA
ENERGY PER ELECTRON, eV
ELECTRON DENSITY, CM^-3
10^4
10^3
10^2
10
10^-2
10^-1
1
10
10^2

Figure 5